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SAND96–0434 • UC–905
Unlimited Release
Printed February 1996

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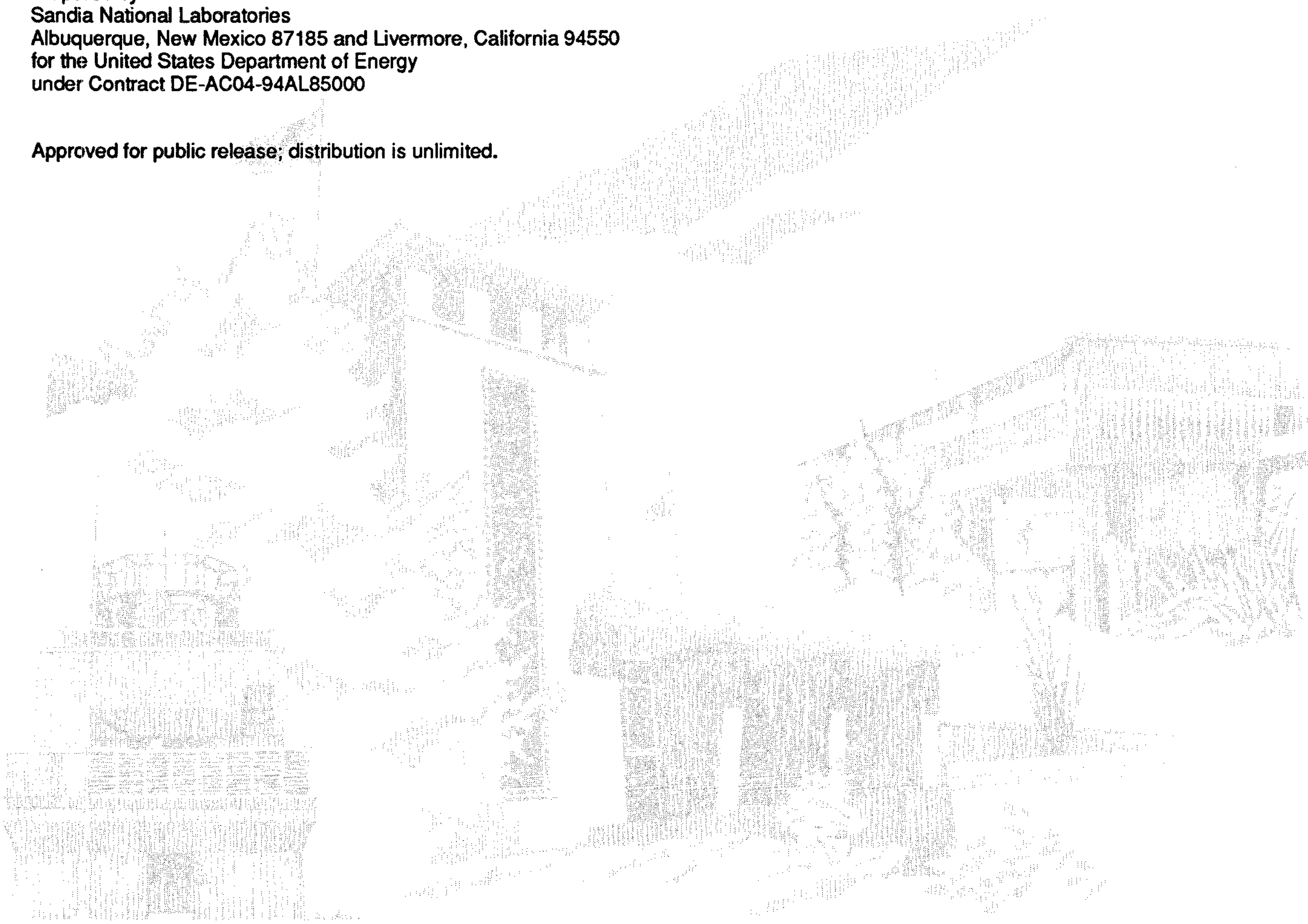
Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-94AL85000



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Distribution
Category UC-905

Development of Aspen: A Microanalytic Simulation Model of the U.S. Economy

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Abstract

This report describes the development of an agent-based microanalytic simulation model of the U.S. economy. The microsimulation model capitalizes on recent technological advances in evolutionary learning and parallel computing. Results are reported for a test problem that was run using the model. The test results demonstrate the model's ability to predict business-like cycles in an economy where prices and inventories are allowed to vary. Since most economic forecasting models have difficulty predicting any kind of cyclic behavior, these results show the potential of microanalytic simulation models to improve economic policy analysis and to provide new insights into underlying economic principles. Work already has begun on a more detailed model.

Development of Aspen: A Microanalytic Simulation Model of the U.S. Economy

Introduction

This report describes the process used to develop a microanalytic simulation model of the U.S. economy. Two key factors distinguish the microsimulation process: 1) Economic decision makers are modeled individually; and 2) a simulation process is used to obtain an economic analysis. Macroeconomic variables–such as gross domestic product, inflation rate, or unemployment rate–are computed as aggregate results of innumerable decisions by the individual, economic decision makers.

The microsimulation model has the potential to improve the accuracy of economic forecasting and to provide new insights into underlying economic principles. More specifically, the microsimulation approach can provide four major advantages over more traditional modeling techniques:

1. It models in greater detail the impact of various legal, regulatory and policy changes–such as monetary policy, tax law, or trade policies.
2. It allows different sectors of the economy to be analyzed independently and/or integrated with other sectors to develop a better understanding of the whole economic process.
3. It accurately simulates the behavior of basic decision-making ***agents*** within the economy, such as households, banks, companies, or government.
4. It models the economy in a single, consistent calculation.

Background

Most well known models of the U.S. economy are either macroeconomic or computable general equilibrium (CGE). Macroeconomic models use complex multivariate regression analysis on aggregate data to represent the economy as a sequence of linear equations. CGE models require the solution of systems of simultaneous equilibrium equations to obtain a forecast.

The economics profession has devoted more than six decades to devising and improving these economic models. In particular, econometric techniques of parameter specification have reached a high degree of sophistication. Hence, the macromodels can provide accurate forecasts. However, problems arise when totally new economic policies are introduced with no past relevant data that can be used to develop modeling parameters.

Although microanalytic simulation models have great potential, at their present level of development they cannot compete with macroeconomic models in terms of forecast accuracy.

To our knowledge, there have been only two major simulation models of the U.S. economy. One is the Urban Institute model, originally developed by Guy Orcutt, which emphasizes the household sector. This model uses macroestimations to derive other sectors and incorporates these sectors through feed-back loops. The other is the Transactions model, developed by Barbara Bergmann, which is a nonstochastic, semimacro construct.

The relative scarcity of microsimulation models can be attributed to two factors: 1) Microsimulating something as large and complex as the U.S. economy requires extensive calculation time and computer resources; and 2) the microdata, which is needed to correctly parameterize the microequations, has not been readily available.

However, computing capacity is rising, and in particular, the field of parallel computing is rapidly progressing. New advances in evolutionary learning models, such as genetic algorithms and neural networks, have given microsimulation the tools to better simulate human behavior. Finally, there has been a tremendous increase in the availability of microstatistics. All of these factors have contributed to creating an environment that is conducive to the development of new microsimulation techniques.

The Microanalytic Simulation Model

The Sandia-developed microanalytic simulation model, called Aspen, uses time-dependent Monte Carlo methods to advance the solution forward in time. These methods are ideal for investigating the behavior of complex, nonlinear stochastic systems, like the economy. The economic agents interact, or communicate, with one another via transactions. Most transactions are purchases, although others may be bank deposits or the exchange of information. The objective of a transaction is to mimic what goes on in an actual economy.

Time is divided into increments corresponding to days, and the state of each agent (i.e., saving account balance, family size, bond holdings, etc.) is known at the beginning of the day. Aspen's agents start each day making decisions, much like their real-life counterparts. Decisions on actions to take are based either on probabilities computed from actual microeconomic data or on results of learning models. The simulation traces the agents' daily transactions as they buy food, hire workers, sell bonds, collect welfare payments, conduct open market operations, etc. The agents' states are updated at the end of the day by reviewing their transaction histories.

By following the time histories of these economic agents, numerous interaction possibilities can be investigated. The potential for discovering new and important economic effects and options also is enhanced.

Aspen represents the "next generation" in microsimulation technique, providing the following improvements over previous micromodeling efforts:

- Aspen is designed to run on Sandia's massively parallel Intel™ Paragon, currently the world's fastest computer.

  Through use of the Paragon, it is anticipated that the entire economy can be microsimulated in sufficient detail to be realistic. This would eliminate the need to rely on macroeconomic behavioral equations to "fill in" missing sectors of the economy. Instead, microeconomic equations would be used to model behavior, and macroeconomic identities would be applied to calculate important macrovariables.

- The economic agents can communicate with one another and make "real life" decisions.

  One of Aspen's key features is its ability to realistically represent the process used by the economic agents to maximize utility or profit. Agents can adapt their behavior dynamically, according to changing economic conditions and past experience, through evolutionary learning models.

The Prototype Model

A prototype model of Aspen has been developed to test code structural issues and message-passing algorithms across nodes of the Paragon.

The prototype consists of two computer programs. The user interacts with the first program by defining the problem to be run. This program submits the compute job to the Paragon and controls calculation progress. After the job is complete, it displays the calculation results at the user's terminal. The second program is the compute engine that solves the Monte Carlo problem. It runs in the compute partition of the Paragon and employs the number of compute nodes specified by the user.

The Aspen prototype model is a rudimentary model of a simple market economy. The model contains three classes of economic agents: government, firms in a single industry, and households. The flow of money for the model is shown in Figure 1.

The government's functions are to collect taxes from both the industrial and household agents and to pay benefits to unemployed individual agents.

The industrial agents (firms) produce a product that is consumed by the household agents on a daily basis, such as food. Firms hire individual agents to produce the product and to maintain sufficient inventory. When a firm's inventory is greater than 30 days worth of sales, it lays off workers. When its inventory is less than 10 days worth of sales, it hires workers. Firms compete with one another by varying the price of the product they sell. A genetic algorithm, learning-classifier system is used to simulate pricing strategy.

A household's demand for the commodity is a function of income and family size, and it is more likely to buy from firms with more cheaply priced products. Income depends on whether the head-of-household is employed or receiving unemployment benefits. Workers that are employed have greater income and, therefore, buy more product. The household head can also make a decision to switch jobs based on differences in wages offered by the firms.

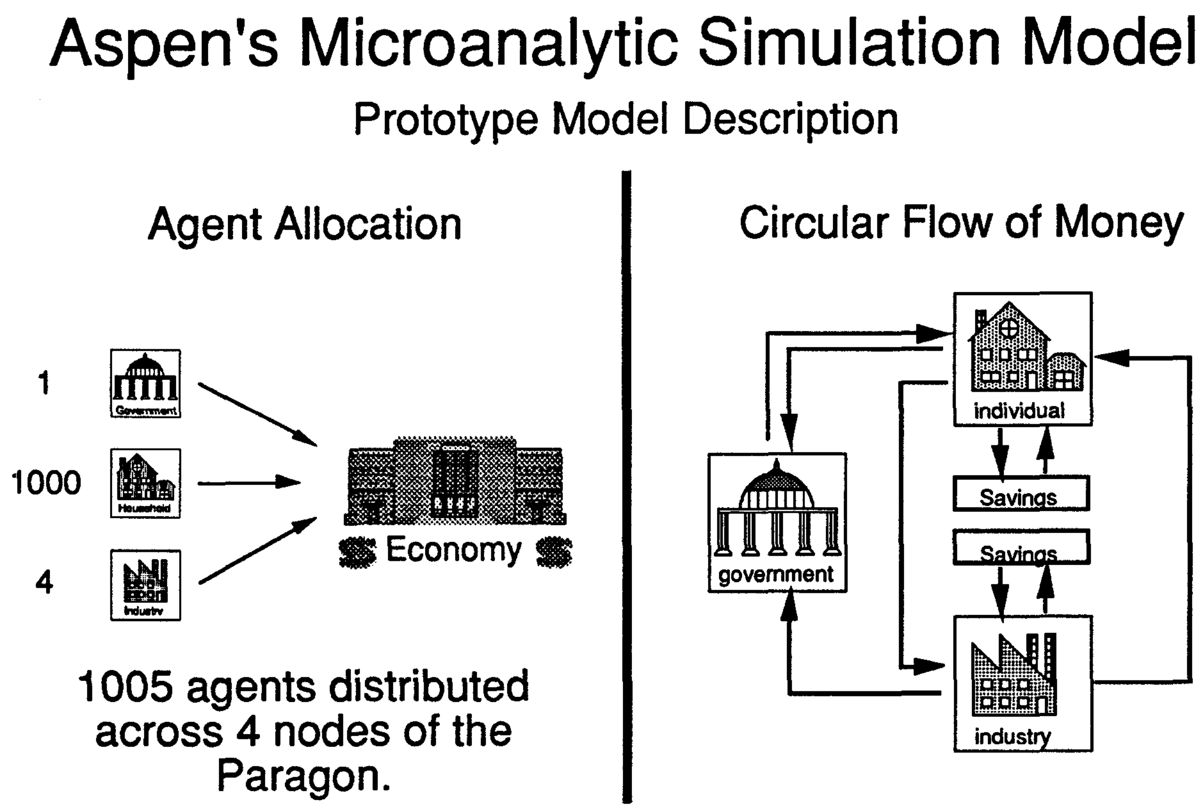

Figure 1. Agent allocation and flow of money for test problem.

Results Using The Prototype Model

The graph in Figure 2 shows an example of a run using the prototype model, with the Paragon performing calculations to about 30 years of problem time. The time-cycle step size for the problem is constant and is assumed to be one day. The calculation includes 1,000 households, four firms in a single industry, and one government. The total product sales (in units) for the industry are shown over the 30-year time period.

The short period cycles are due to hiring and layoff decisions by the firms. The longer period cycles, which are approximately seven years in duration, are more business-cycle-like in nature. These cycles result from pricing decisions of the firms and inventory excesses.

These calculation results suggest that both the modeling and agent-learning approaches are proceeding in the right direction. Further, the results demonstrate the ability of the prototype model to predict business-like cycles in an economy where prices and inventories are allowed to vary. Since most economic forecasting models have great difficulty predicting any kind of cyclic behavior, these results are highly encouraging.

This prototype Aspen model is now being made available through Sandia's TIE-In system.

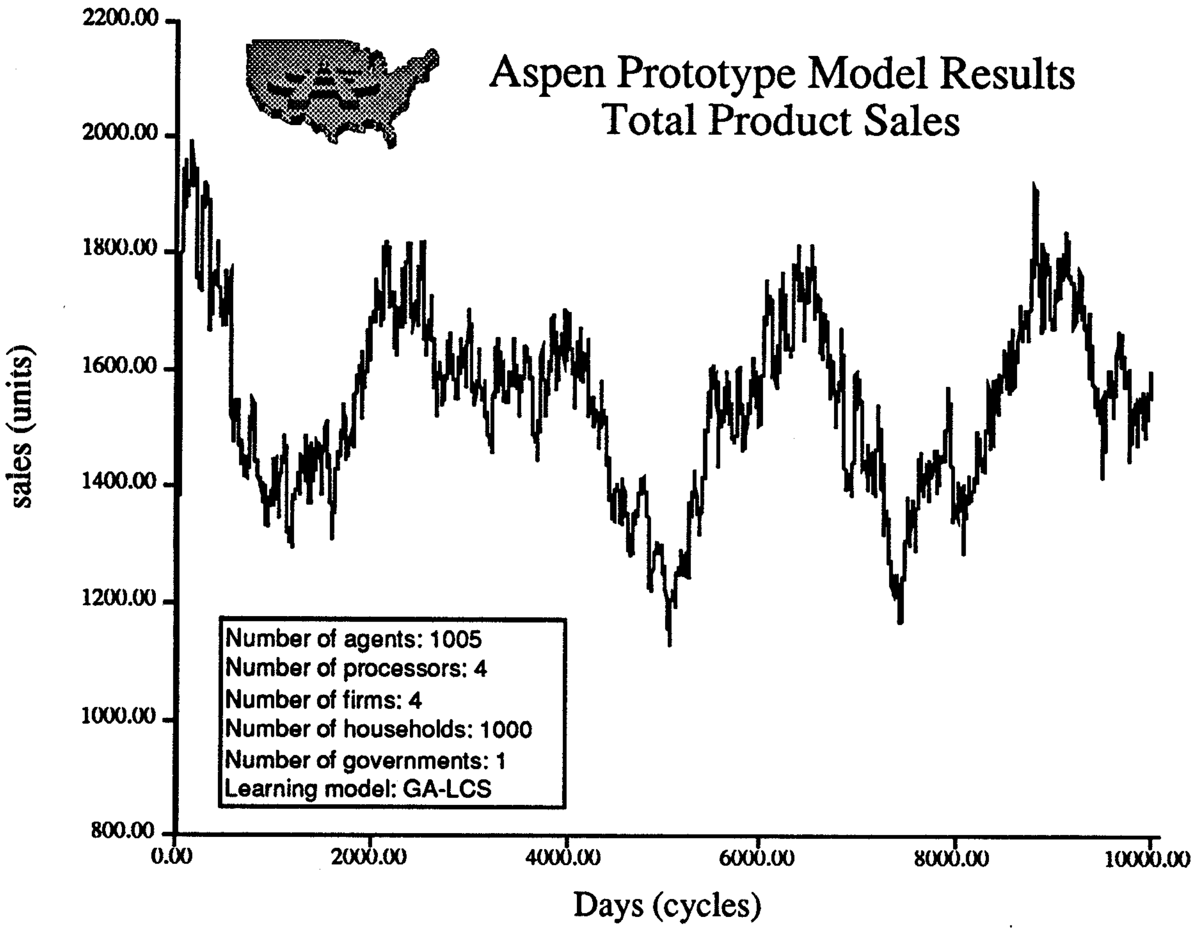

Figure 2. Total product sales from all firms.

The Developmental Model

Work has begun on a more detailed developmental model, which is scheduled for availability on the TIE-In system in the May 1996 timeframe. This model includes a banking system, the Federal Reserve, a bond market, a real estate market, and various types of industry. An emphasis on interest-sensitive sectors of the economy is expected to make the developmental model of Aspen particularly useful in analyzing monetary issues.

Conclusion

At the present level of development, microsimulation models cannot compete with macroeconomic models in terms of forecast detail and accuracy. However, they have shown the potential to improve policy analysis and to provide new insights into underlying economic principles. Eventually, microsimulation not only can complement the various macroeconomic and CGE models, but it can also provide superior analysis and forecasting power.

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